Faculty of Engineering
3rd year MechanicalDesign and Production Department

Grinding

1- مصطفى ممدوح عبد الله عمر	4
2- محمد وجيه نعيم محمد	4
3- محمد عادل السيد علي	3
4- أحمد إبراهيم أحمد شحاته	1
5- أحمد جمال عبد الرازق عطيه	1
6- محمد أحمد زغلول محمد	3
7- محمد أحمد سيد محمود	3
8- محمد أحمد محمد أحمد الجلداوي	3
9- كريم مجدي سعد حسن	3

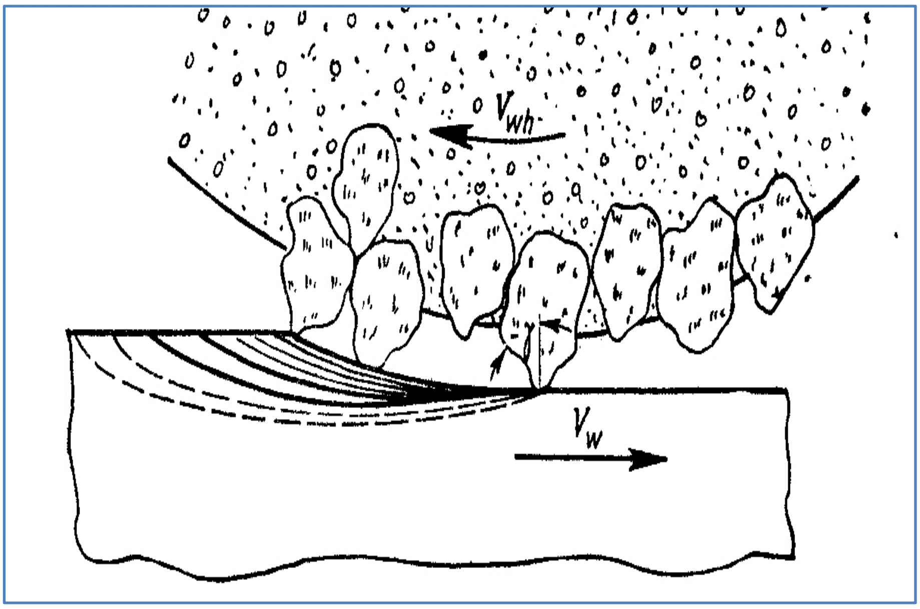
إلى: د.وائل عقل

التاريخ: 16/5/ 2011

Introduction

Definition:

Grinding is the most common form of abrasive machining. It is a material cutting process which engages an abrasive tool whose cutting elements are grains of abrasive material known as grit. These grits are characterized by sharp cutting points, high hot hardness, chemical stability and wear resistance. The grits are held together by a suitable bonding material to give shape of an abrasive tool.



Advantages of grinding:

- dimensional accuracy
- good form and locational accuracy
- Extremely smooth finish desirable at contact and bearing surfaces can be produced by grinding operation due to large number of cutting edges on the grinding wheel.
- No surface marks because the wheel has considerable width.
- Very accurate dimensions and smoother surface finish can be achieved within short time.
- Complex profiles can be produced accurately with relatively inexpensive turning templates.
- Grinding is the only method of removing material from materials after hardening.

Applications of Grinding Wheel :

- To remove a very small amount of metal from the workpiece to bring its dimensions within very close tolerances.
- To obtain better finish on the surface.
- To machine hard surfaces which are otherwise difficult to be machined by the high speed steel tools or carbide cutters.
- To sharpen the cutting tools.

Grinding Operations

Main technique:

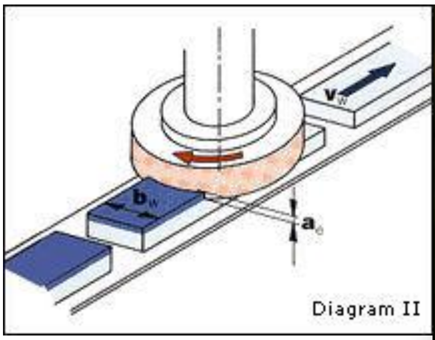
In grinding for material removal, the method used is called abrasion. In other words, in grinding, an abrasive material rubs against the metal part and clears or removes tiny pieces of material. The process implies that instead of cutting like a lathe bit, the material is slowly and steadily worn away. This is because compared to the material being ground, the abrasive is harder. The grinding wheel actually acts like many hundreds of very small lathe bit, each cutting off some metal. The abrasive must be strong enough to bear any kind of forces acting upon it while grinding. Usually some sort of impact shock occurs when the abrasive comes in contact with the material. Grinding abrades material in a way similar to sanding. The grinding operation is performed on a several machines like the lathe and the mill, with the appropriate add-on accessories, the most important of which is the spindle.

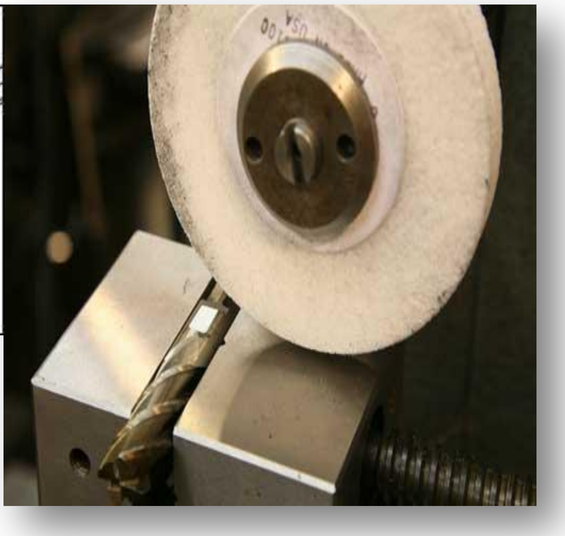
Types of grinding:

Grinding can be of various types, like as follows:

a. **Surface grinding**
b. **Centered grinding**
c. **Plunge grinding**
d. **Centerless grinding**
e. **Contour grinding**
f. **Diamond Grinding**
g. **Creep-feed grinding**

A. Surface grinding:



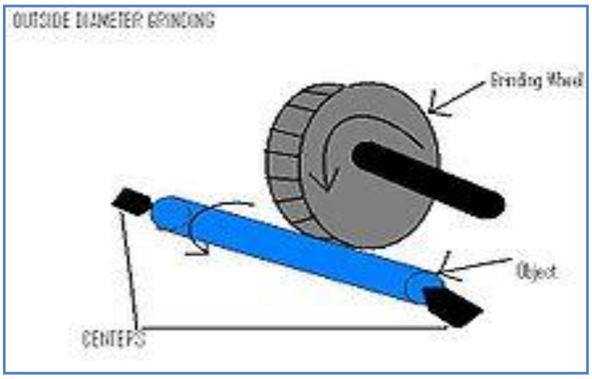


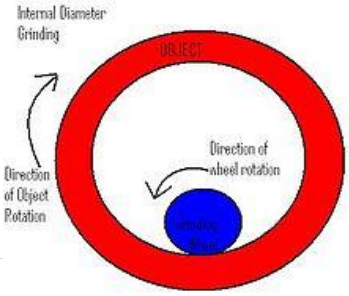
- This is perhaps the most fundamental of operations. Surface grinding is the process of providing precision ground surfaces either to a critical size or for the surface finish. In other words, it accurately processes or grounds a surface.
- It may be peripheral or face.
- Parts require surface grinding for various reasons like:

  - Produce a flat surface.
  - For specifying accurate tolerance thickness.
  - A very smooth surface toughness is required.
  - For sharpening of cutting tool.

B. Centered grinding:

- In this type of grinding, the grinding is performed at the center.
- For cylindrical products.
- There are two types of centered grinding-OD grinding and ID grinding.
  1. In Outside Diameter (OD) grinding, the work piece has center drilled ends, accommodating center points and surface is removed by rotating the grinder's face plate. With OD grinding the work piece and the grinding wheel moves or rotates in clockwise directions.
  2. Inside Diameter (ID) grinding is performed on tubular parts that are generally held in a chuck or collet. The grinding wheel turns at very high speed to maintain the proper surface speed but it moves anticlockwise.

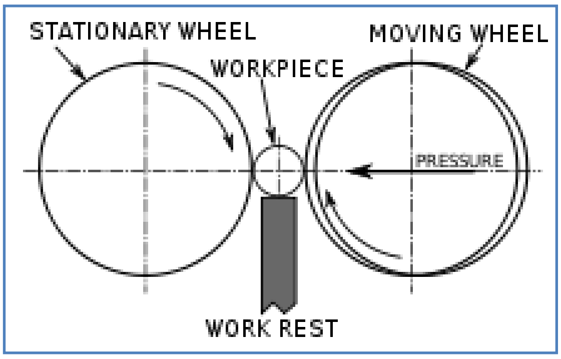



Internal Diameter Grinding
OBJECT
Direction of wheel rotation
Direction of Object Rotation

C. Plunge grinding

A form of OD grinding, however the major difference is that the grinding wheel makes continuous contact with a single point of the object instead of traversing the object

D. Centreless grinding



Is a form of grinding where there is no collet or pair of centers holding the object in place? Instead, there is a regulating wheel positioned on the oppositeside of the object to the grinding wheel. A work rest keeps the object at the appropriate height but has no bearing on its rotary speed. The workblade is angled slightly towards the regulating wheel, with the work-piece centerline above the centerlines of the regulating and grinding wheel; this means that high spots do not tend to generate corresponding opposite low spots, and hence the roundness of parts can be improved. Centerless grinding is much easier to combine with automatic loading procedures than centered grinding; throughfeed grinding, where the regulating wheel is held at a slight angle to the part so that there is a force feeding the part through the grinder is particularly efficient.

E. Contour grinding:

In case of contour grinding, the chopping function is used to grind the side face of a work-piece.

F. Diamond grinding

Is a grinding process that can be applied to a variety of surfaces including floors, stones and engineering ceramics? It takes advantage of the fact that diamond has the highest hardness of any bulk material.

G. Creep-feed grinding

Creep-feed grinding (CFG) was invented in Germany in the late 1950s by Edmund and Gerhard Lang. Unlike normal grinding, which is used primarily to finish surfaces, CFG is used for high rates of material removal, competing with milling and turning as a manufacturing process choice. Depths of cut of up to 6 mm (0.25 inches) are used along with low work-piece speed. Surfaces with a softer-grade resin bond are used to keep work-piece temperature low and an improved surface finish up to 1.6 micrometersR_{max}

Other types:

Form grindingis a specialized type of cylindrical grinding where the grinding wheel has the exact shape of the final product. The grinding wheel does not traverse the work-piece.

Internal grinding is used to grind the internal diameter of the work-piece. Tapered holes can be ground with the use of internal grinders that can swivel on the horizontal.

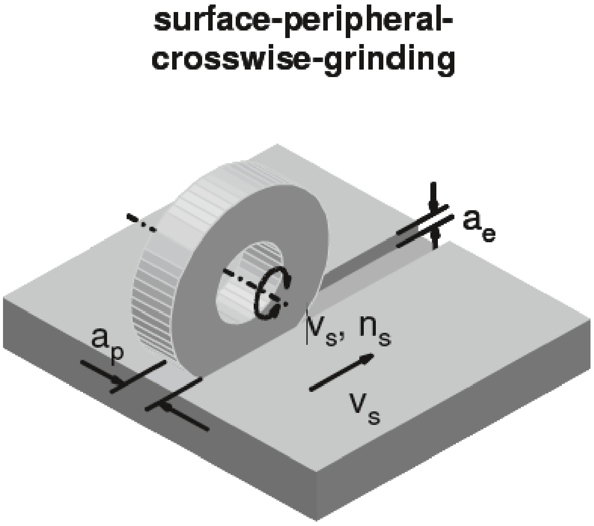
Lubrication

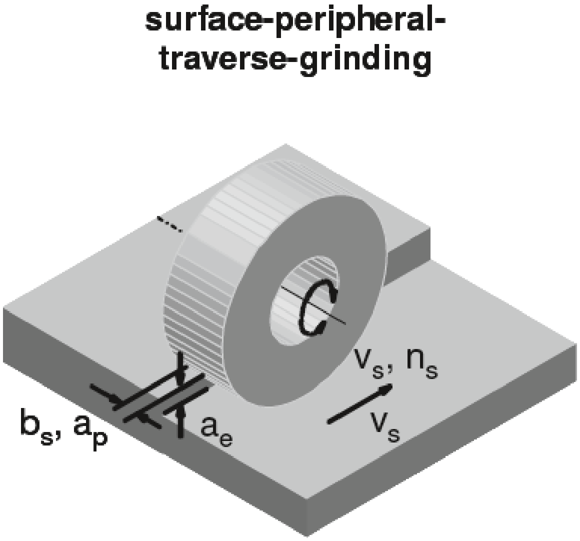
The use of fluids in a grinding process is necessary to cool and lubricate the wheel and work-piece as well as remove the chips produced in the grinding process. The most common grinding fluids are water-soluble chemical fluids, water-soluble oils, synthetic oils, and petroleum-based oils. It is imperative that the fluid be applied directly to the cutting area to prevent the fluid being blown away from the piece due to rapid rotation of the wheel.s

Work Material	Cutting Fluid	Application
Aluminum	Light duty oil	Flood
Brass	Light duty oil	Flood
Cast Iron	Heavy duty emulsifiable oil, light duty chemical oil, synthetic oil	Flood
Mild Steel	Heavy duty water soluble oil	Flood
Stainless Steel	Heavy duty emulsifiable oil, heavy duty chemical oil, synthetic oil	Flood
Plastics	Water soluble oil, dry, heavy duty emulsifiable oil, dry, light duty chemical	

Surface Grinding

Surface grinding is the most well-known process of the grinding operations. A rotating wheel is used in the surface grinding which is used for grinding flat surfaces. However, the grinding wheel is not limited to just a cylindrical shape but it can have a myriad of options that are useful in transferring different designs to the object being worked on. When surface grinding an object takes the shape of the wheel will be transferred to the material of the object like a mirror image. The diamonds are used to remove the abrasive material which is unwanted and to give the desired geometry to the work piece. Surface grinding is a finishing process that smooths the surface of metallic or non metallic materials and gives them a more refined look.



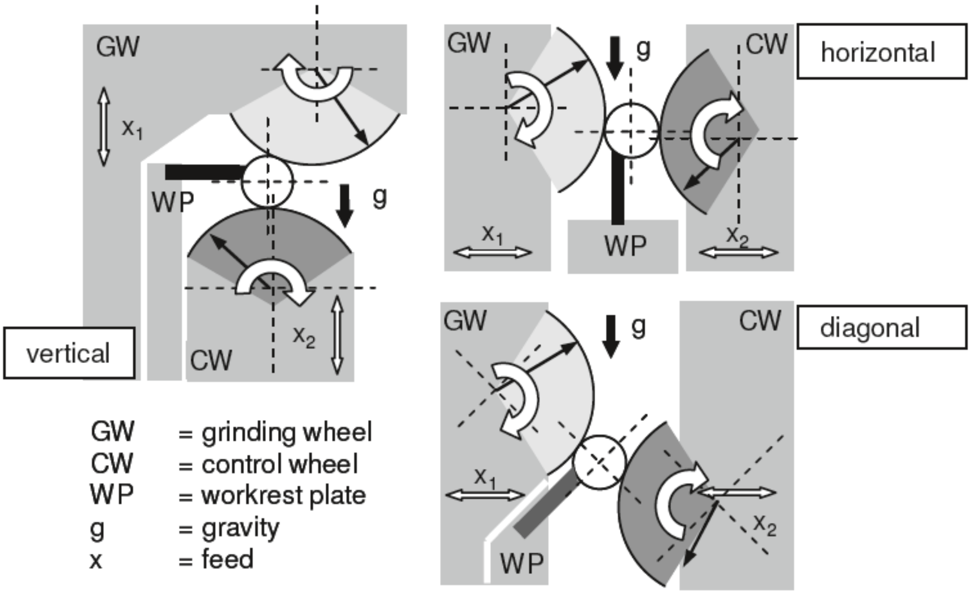


The surface grinder is comprised of an abrasive wheel, a work-holding device known as a chuck either electromagnetic or vacuumand a reciprocating table. Depending on the material being worked on and the desired surface finish the wheel's abrasive material can vary from aluminium oxideto silicon carbideand from diamond to cubic boron nitride. The chuck is a device that is used to hold the material in place while it is being worked on. It can do this one of two ways- metallic pieces are held in place by a magnetic chuck while non-metallic pieces are vacuumed in place. During the grinding process, the work piece must be flooded with a coolant so as to keep it cool and also to keep the excess shavings from building up. There are different types of coolants that are used depending on the material that is being worked on. The most common are: water-soluble chemical fluids, water-soluble oils and synthetic oils. In applying the coolant, care should be taken to apply the liquid directly to the location of the grind. It must be ensured the coolant reaches the material and is not deflected by the grinder wheels at high speeds. Typical work piece materials include cast iron and minor steel. These two materials don't tend to block the grinding wheel while being processed. Other materials are aluminium, stainless steel, brass and plastics. The three most important factors to consider when surface grinding is: the material of the grinding wheel, the material of the piece being worked on, and the grinding fluid. If proper grinding fluid is not used then the surface finish will not be completely smooth. When grinding at high temperatures, the material tends to become weakened and is more inclined to be corroded. This can also result in a loss of magnetism in materials where this is applicable. The tolerances that are normally achieved with grinding are 2×10^{-4}inches for a grinding a flat material and 3×10^{-4}inches for a parallel surface. When working with any type of grinder, one should always be cognizant of safety procedures in order to avoid injury.

Centerless Grinding

Centerless grinding is a method of material removal through grinding, similar to centered grinding except for the absence of the spindle. It has high throughput, i.e. a large number of parts can be manufactured in a short time.

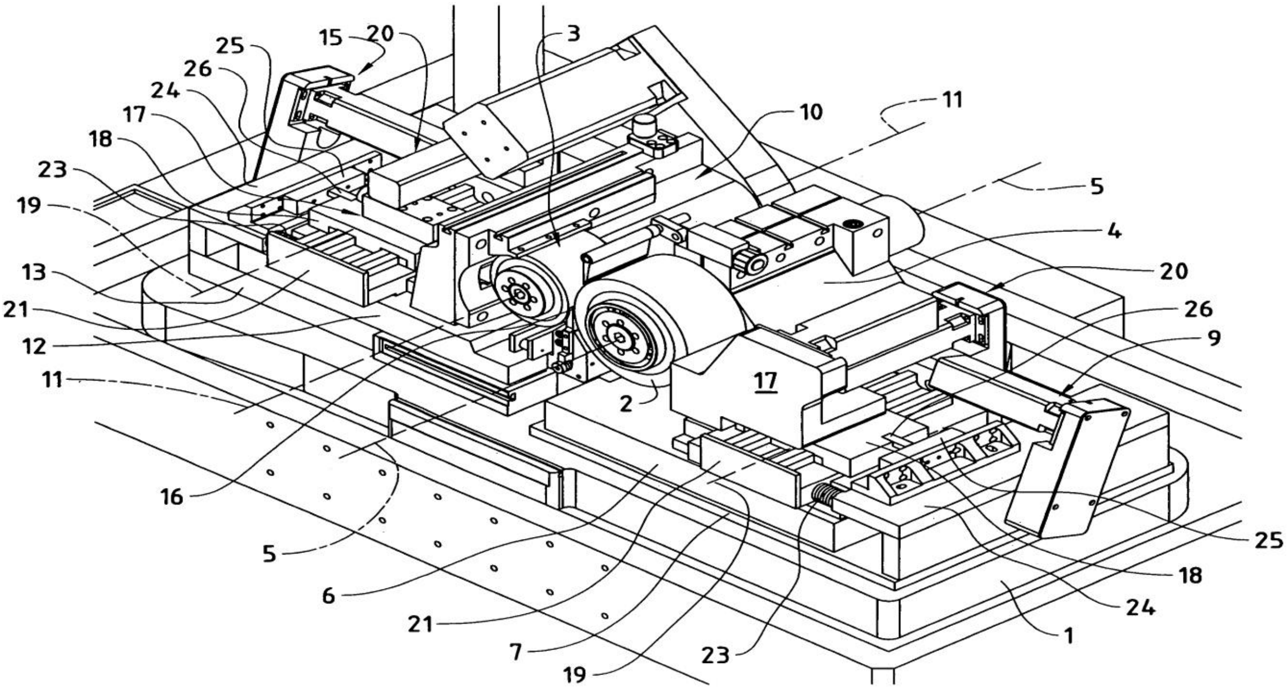
The workpiece is set up between the regulating wheel (or back up wheel) and the grinding wheel, and is supported by the work blade (or work rest). The work rest is located between the wheels. The work is placed upon the work rest, and the latter together with the regulating wheel is fed forward forcing the work against the grinding wheel. Axial movement of the work past the grinding wheel is accomplished by tilting the regulating wheel at a slight angle from horizontal. An angular adjustment of 0 to 8 or 10 degrees is provided in the machine for this purpose.



Centerless grinding is classified into two types:

- Throughfeed grinding - the workpiece is fed into the machine along the work blade
- Plunge grinding - the workpiece is placed between the wheels on a work blade and the grinding wheel is plunged into the workpiece.

Some of the benefits of centerless grinding include the ability to grind parts with geometries that do not allow them to be OD ground, the ability to remove three, five and other odd numbered lobbing on the shaft of a part, and to maintain size beyond what is typically capable of an OD grinder due to the low overall pressures spaced out along the workpiece.



3 Reasons to Choose Centerless Grinding over Traditional Grinding

Manufacturing companies today are under tremendous pressure to reduce costs on the production line or face extinction. Choosing the right production process can be the difference to being profitable or losing money on a product line.

Here are three reasons to why it is really a simple decision to know if you should choose centerless grinding over the traditional OD grinding process that has been used for years in manufacturing of round parts.

3. **The Basic Shape or Configuration of Your Part**

The shape or configuration is the most important factor in determining which type of grinding process to select. Parts that are straight and have no undercut are perfect for centerless grinder machines. Also long pieces of material such as steel bars and rods are also ideal. They can be fed across the centerless blade from one side of the grinder moving between the grinding wheel and the regulating wheel and exit from the other side of the grinder very quickly and easily. This style of grinding is called through feed grinding. One part after another is pushed continuously into the machine without having to chuck up or set up another part each time.

4. Process Speed

Another huge advantage is that you do not need to set up or chuck up every part to be machined as mentioned in the previous paragraph. The minimum handling of work pieces and material saves time and increases production speed. Centerless grinders can be equipped with automatic part feeders. The use of automation has made processing speeds faster and labor costs lower. When materials need to be brought into size rapidly, many manufacturers will choose to go with a centerless grinder machine.

5. Dimensional Tolerances

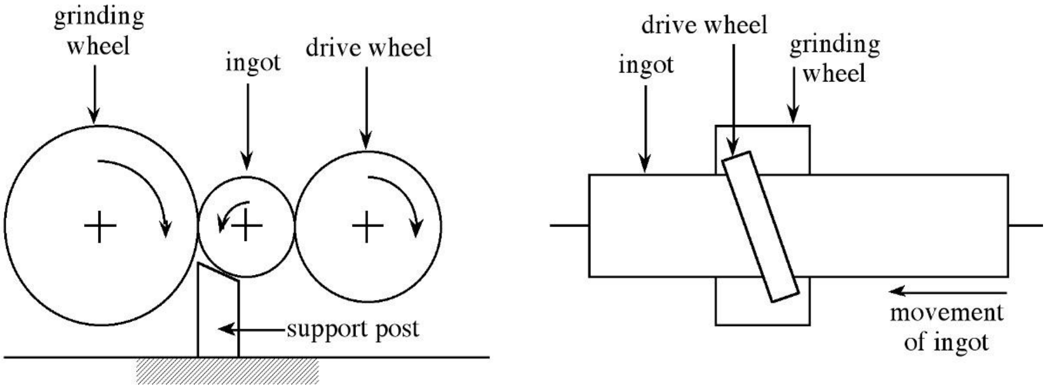
The final reason why manufacturers have moved away from OD grinding is for the tolerance and dimensional accuracy that is necessary for many parts. Tolerances in the millionths of an inch or centimeter can be achieved in the centerless grinding process. Many times traditional OD grinding cannot produce tolerance and size accuracy this rigid. Many products produced today are used in medical and aerospace industries. Usually these parts require very tight or high level dimensional tolerances to meet the manufacturer’s specifications

In summary, every manufacturing company faces decisions as to which processes should be used to ensure that the production line is running as rapidly as possible. The difference in keeping on schedule and lowering costs and most importantly raising profits is choosing the right manufacturing process.

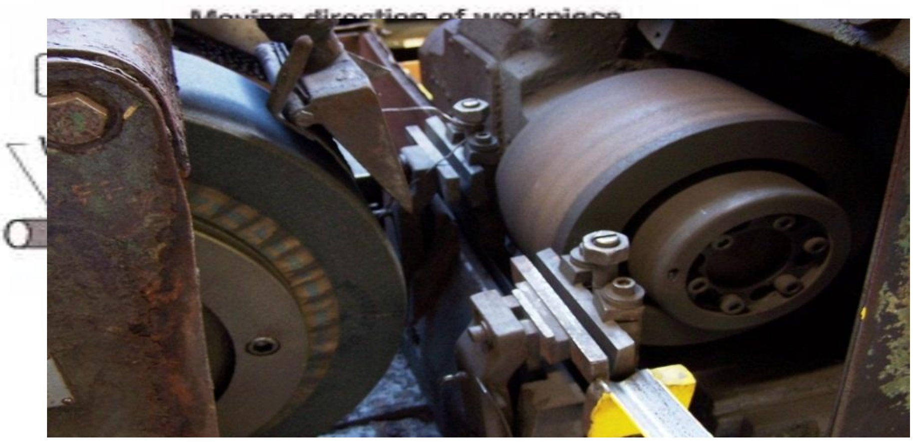
Disadvantages of centerless machine

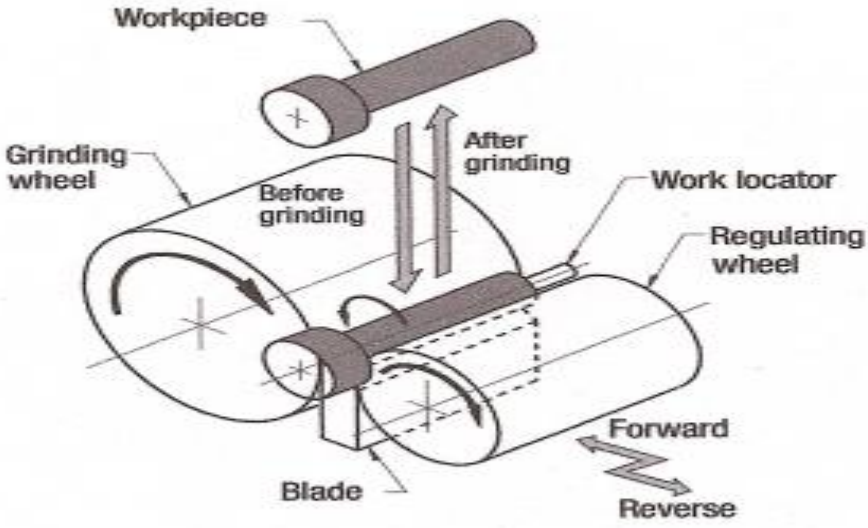
- In hollow w.p the outer diameter not concentric with inner diameter.

- Not easy to grind w.p which have multi diameter.



The basic component of the centerless grinding machine



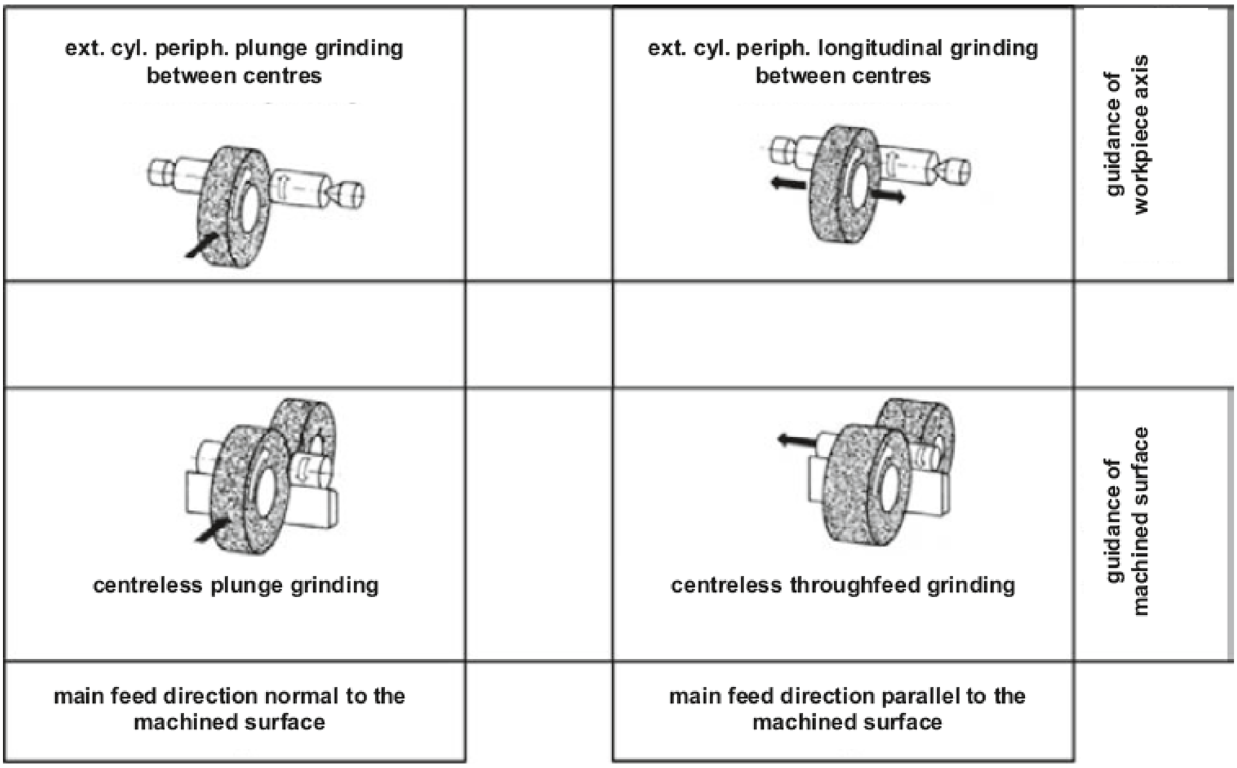


Centerless grinding steps

Surface Grinding

1. External Cylindrical Grinding

External cylindrical grinding is primarily used for machining rotation-symmetricalworkpiece contours and is subdivided by the type of workpiece positioning and main feed directions


ext. cyl. periph. plunge grinding between centres
ext. cyl. periph. longitudinal grinding between centres
guidance of workpiece axis
centreless plunge grinding
centreless throughfeed grinding
guidance of machined surface
main feed direction normal to the machined surface
main feed direction parallel to the machined surface

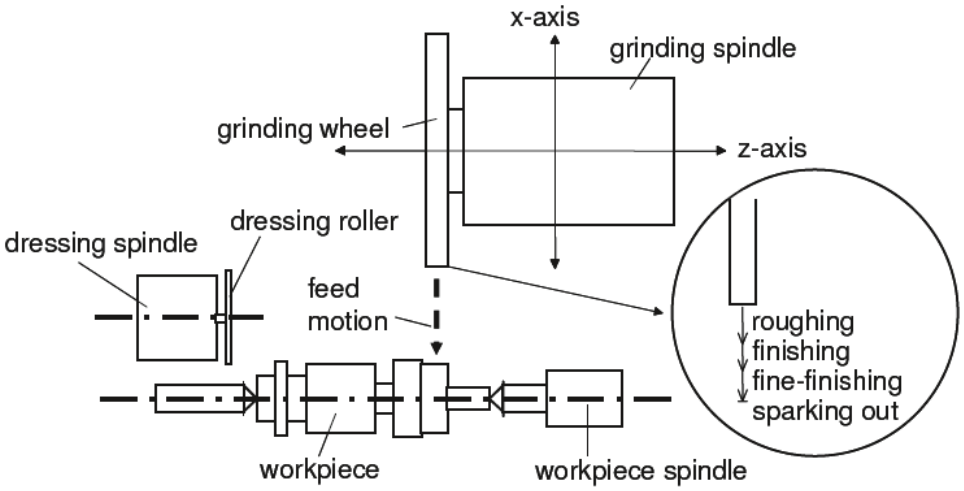
In the case of external cylindrical grinding between centers, the workpiece isclamped in frontal centring components and impelled by means of a workpiece driver. If only small tangential forces appear during grinding, as it is the case for external cylindrical peripheral plunge grinding, then the drive can also occur in a frictionally engaging manner by means of a frontal driver. In centreless grinding on the other hand, the workpiece is positioned on its circumference and driven by the grinding or control wheel. Whether the primary feed directions are orthogonal or tangential to the surface produced is the distinguishing characteristic between external cylindrical peripheral plunge and longitudinal grinding.

a. Between Centres

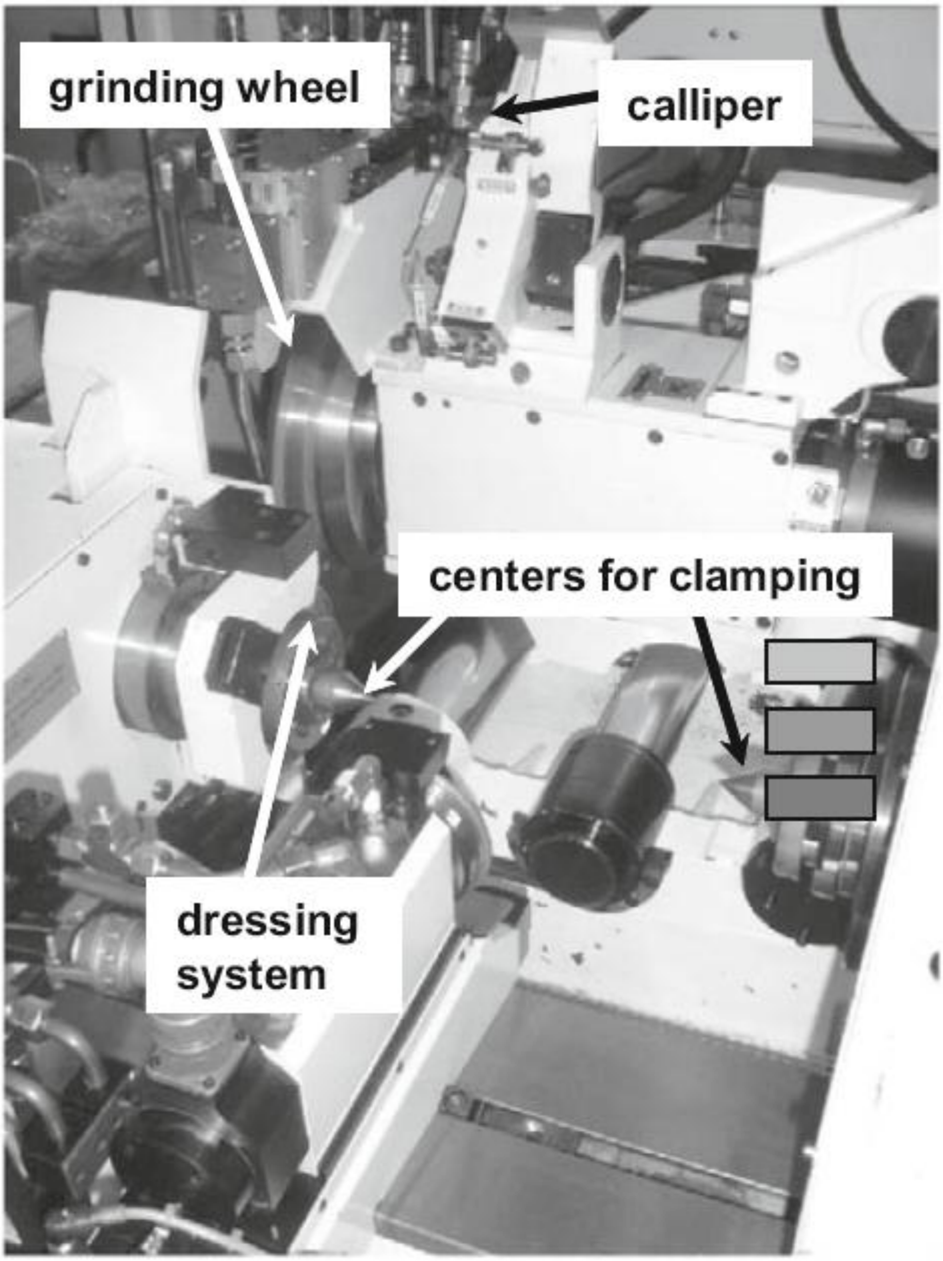
Here, we must differentiate between two methods. In external cylindrical peripheralplunge grinding (infeed grinding), the grinding wheel is arranged normally to the workpiece rotation axis, while in external cylindrical peripheral longitudinal grinding the grinding tool is moved equidistantly to this axis. Both grinding methods generally work with up grinding. In up grinding, the vectors of grinding wheel peripheral speed vs and workpiece peripheral speed vw are directed in opposition of each other in the grinding contact zone. Up grinding is advantageous here because, due to the flatter grain engagement trajectories (see Chapter 2.2), improved surface finish can be achieved. Furthermore, in up grinding, the area of the contact zone is better supplied with cooling lubricant, in which the surface is generated. Yet this effect is in this case not as pronounced as in flat grinding and diminishes with decreasing depths of cut a_e.

External Cylindrical Peripheral Plunge Grinding

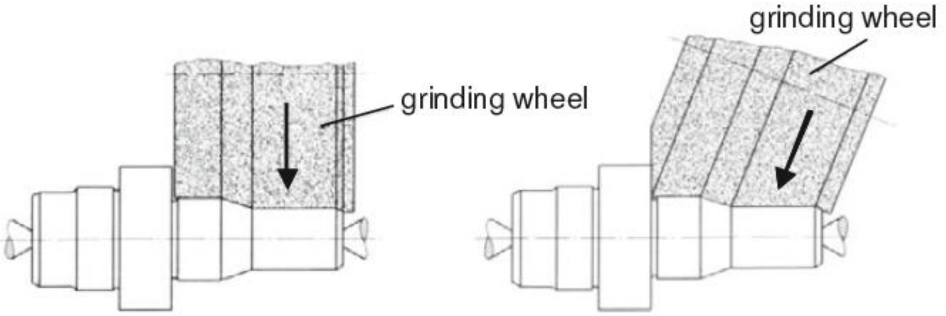
External cylindrical peripheral plunge grinding, also called external cylindrical infeedgrinding, is utilised for machining bearing carriers, shaft cranks and grooves. The next figure shows the schematic arrangement of the grinding wheel, workpiece spindle and the dressing spindle as well as the axes and the direction for the feed setting. The infeed can be subdivided into several process phases, which are distinguished by the fact that, with each further phase, there is a smaller specific material removal rate. During spark-out, no radial infeed setting takes place. In this way, shape errors attributable to deformations caused by machining forces, can again be partially balanced out. Furthermore, by lessening the machining rate towards the end of the process, we can improve the surface quality.



In order to guarantee consistent quality in batch production, a measuring deviceis often employed, which measures the workpiece in the x- and y- direction before grinding in order, for example, to determine exactly the position of the cylinder to by ground as well as the adjacent shoulder. By doing this, the radial safety measure can be reduced, which saves time and lessens the danger of collision with the abutting shoulder



One variant of cut-in grinding is angle cut-in grinding. High plane shouldersand peripheral areas can be produced in one infeed by means of an angled grinding wheel rotation axis. With this manufacturing method, there are clear time advantages in comparison with straight infeed grinding. In particular, the angled position of the grinding wheel in contrast infeed grinding reduces the grinding contact length on the plane shoulder, reducing the danger ofthermal structural damage. The advantages are most evident in processing shaftcrank with considerably varying diameters, which are machined with a wide grinding wheel or a set of grinding wheels. Cutting speed differences, which appear in straight infeed grinding when machining these components, can be balanced out to the greatest extent by setting the grinding wheel at an angle. Infeed with a wide set of grinding wheel, where all functional areas are machined simultaneously, is a highly productive, yet also very inflexible method. With such a disc set, often only a single geometry can be produced. This method is therefore only practical with a certain batch size. Because of the wide grinding wheel making contact, strong forces take effect, so that, besides the workpiece deflection, one must also be mindful of workpiece drive with high torque. Especially when machining thin, slender components, the use of a steady rest is necessary in order to avoid impermissibly high deformation of the workpiece due to machining forces.

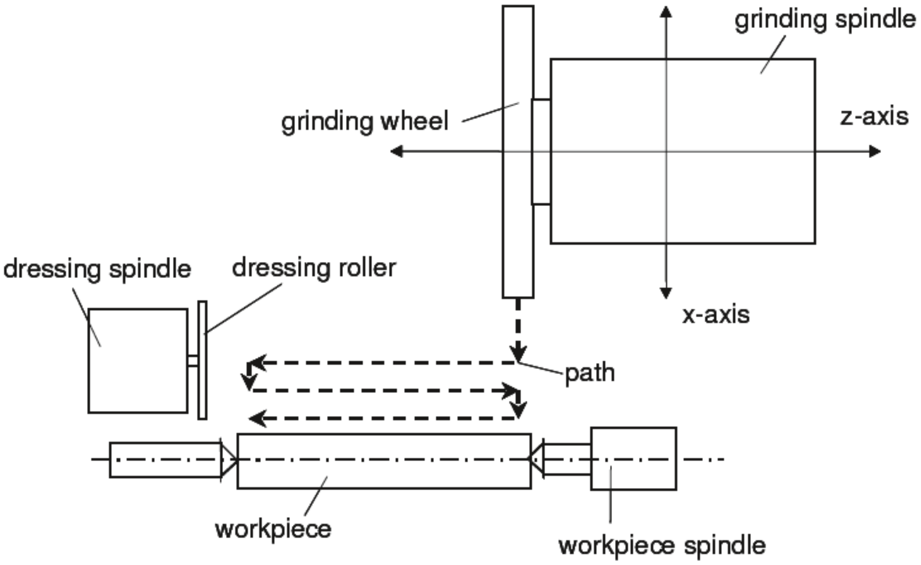


external cylindrical
peripheral
plunge grinding

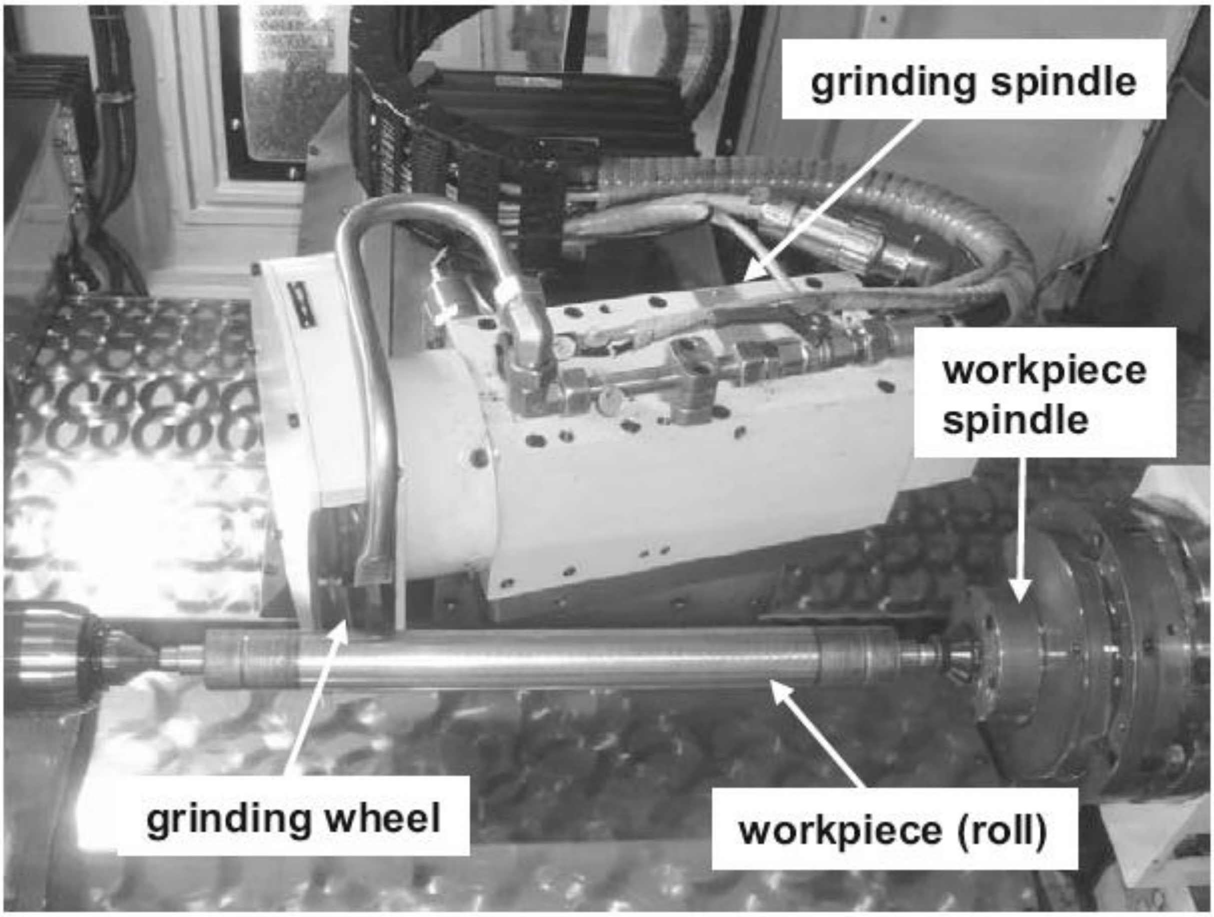
external cylindrical
peripheral
angle grinding

External Cylindrical Peripheral Longitudinal Grinding

External cylindrical peripheral longitudinal grinding between centres is used tomanufacture cylindrical and conical workpieces, if the workpiece length to be machined is much larger than the grinding wheel width. The main field of application of this grinding technique is in machining print cylinders, cylinders for paper manufacture and for steel mills. In this technique, the grinding wheel moves along the workpiece, which is clamped between centres. At the reversal points, the feed motion occurs normal to the workpiece surface. After the transition into the feedmotion with the set speed, one sideof the grinding wheel comes into contact withthe workpiece

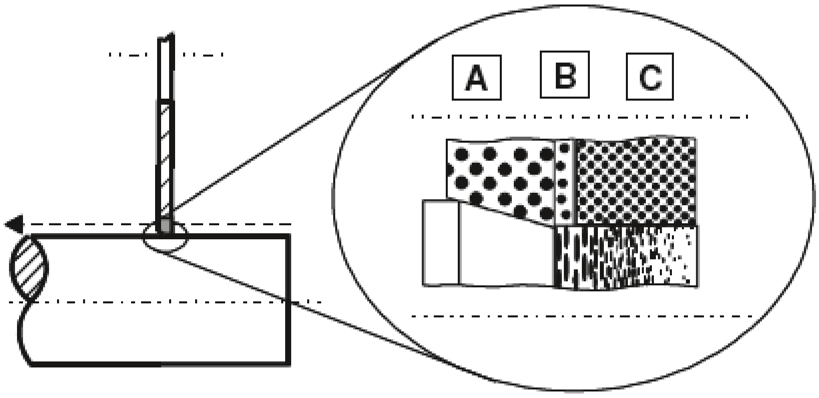


Generally, it is possible to remove the total allowance in only one grindingstroke, designated as peel grinding, or in several strokes. These variants are distinguishedin a manner similar to deep and pendulum grinding in the case of flat grinding. Especially appropriate for this are grinding wheels with particularly wear-resistant grain materials like cBN, since in this case the stress on the grinding wheel edge is much higher than in pendulum grinding with only small radial depths of cut.



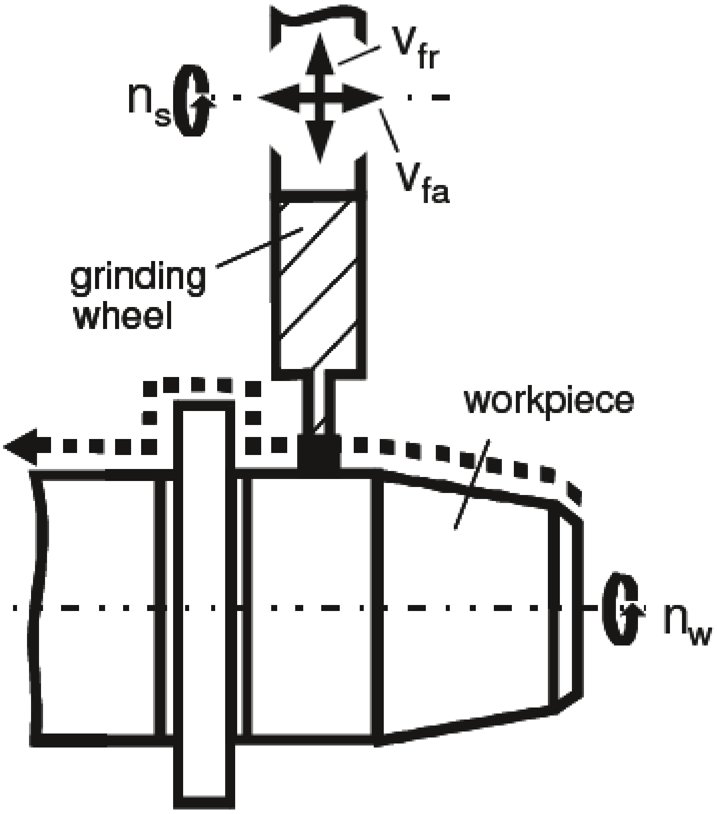
As a result of grinding wheel wear, a step-shaped wear profile is formed that ischaracteristic for external cylindrical peripheral longitudinal grinding. This causes the width of the roughing zone to get constantly larger. The width of the spark-out zone b_{sa}diminishes correspondingly.

In some applications, the grinding wheel is already shaped with a roughingzone geometry during the preparatory stage. In this way, a roughing zone which changes in an unregulated way at the start of the process is avoided. The transition between the roughing and spark-out zones can sometimes be executed with an additional finishing zone. The next figure illustrates the various zones of a grinding wheel for the external cylindricalperipheral plunge grinding of cylindrical workpieces. In zone A, theroughing zone, the largest amount of material is removed. The workpiece surface created in this area is grinded again in the subsequent workpiece rotation. The influence of this zone on the workpiece surface finish is thus minimal. A sufficiently large chip space and a high grinding wheel effective surface roughness and the main requirements on the grinding wheel roughing zone. The finishing zone (B)has only a small width, which usually corresponds to the feed a_f. Here, residual material is removed and the workpiece surface is created to a large extent. A high cutting edge number with minimal chip spaces is advantageous for this purpose. Theoretically, in the spark-out zone (C), no more material removal takes place. By means of the smoothing of the roughness peaks which occurs here, the surface quality is improved. A large amount of active grain cutting edges as well as flattened abrasive grains are advantageous for this.



External Cylindrical Form Grinding

External cylindrical form grinding is a technique variant of external cylindrical peripherallongitudinal grinding. By overlaying the main axial feed movement with an additional radial feed movement, under NC operation, various rotation symmetrical workpiece geometries can be produced. The goal of this technique is to finish grinding the workpiece in one clamping. For this purpose, the entire grinding allowance is removed in one overrun (peel grinding). Due to high grinding wheel stress, highly wear-resistant grinding wheels with diamond or cBNgrains are used primarily. External cylindrical form grinding with grinding wheels of superabrasive grain materials is a high-performance grinding technique. By using slim grinding wheels with a width in the range of 5 mm, a high flexibility is obtained with respect to the producible workpiece contour. Moreover, the advantages of high-speed technologies can be exploited. In this way, a good quality surface finish is attainable, even at high material removal rates.

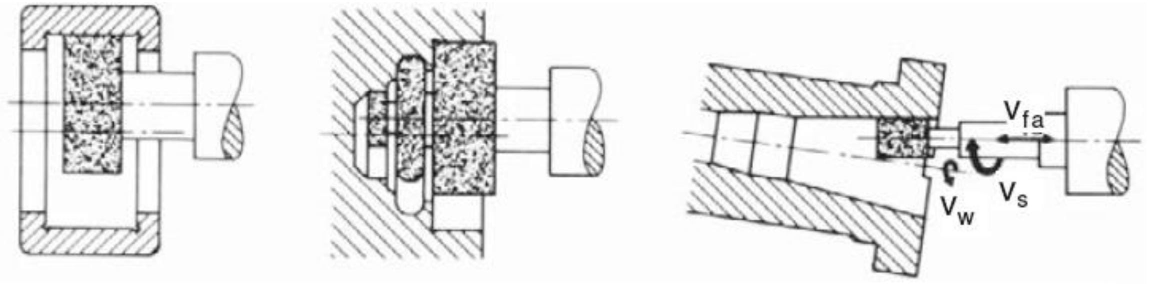


2. Internal Cylindrical Grinding

As in the case of external cylindrical grinding, internal cylindrical grinding is also classified as

- Internal cylindrical peripheral crosswise grinding (plunge grinding) or
- Internal cylindrical peripheral longitudinal grinding (longitudinal grinding).

The kinematics of internal cylindrical grinding is identical to that of the external cylindrical grinding methods between centres already described. The equations derived there for the specific material removal rate are thus valid here as well. Some application examples are shown in the next figure. While the grinding of various notches (b.) involves pure plunge grinding and inside tapers (c.) involve longitudinal grinding, in example (a.) a combination of both methods is used. After a radial infeed, there is a movement lengthwise, since the surface to be machined is in this case wider than the grinding wheel. The workpieces have to be clamped on the outer edge, as accessibility to the inner hole must be guaranteed. This can be achieved by means of a three-jawchuckas well as, for example, by means of gears with the help of a special construction. In this case, the gear is tightened by means of the teeth system. The disadvantagesof tightening the components in a jaw chuck in comparison to clamped between centres is reduced radial precision as well as deformation of the components caused by the jaws. The last point is especially relevant in the case of thinwalledcomponents (e.g. roller bearing rings). After relaxing the elastic deformation, the roundness of the machined surface is thereby no longer given.

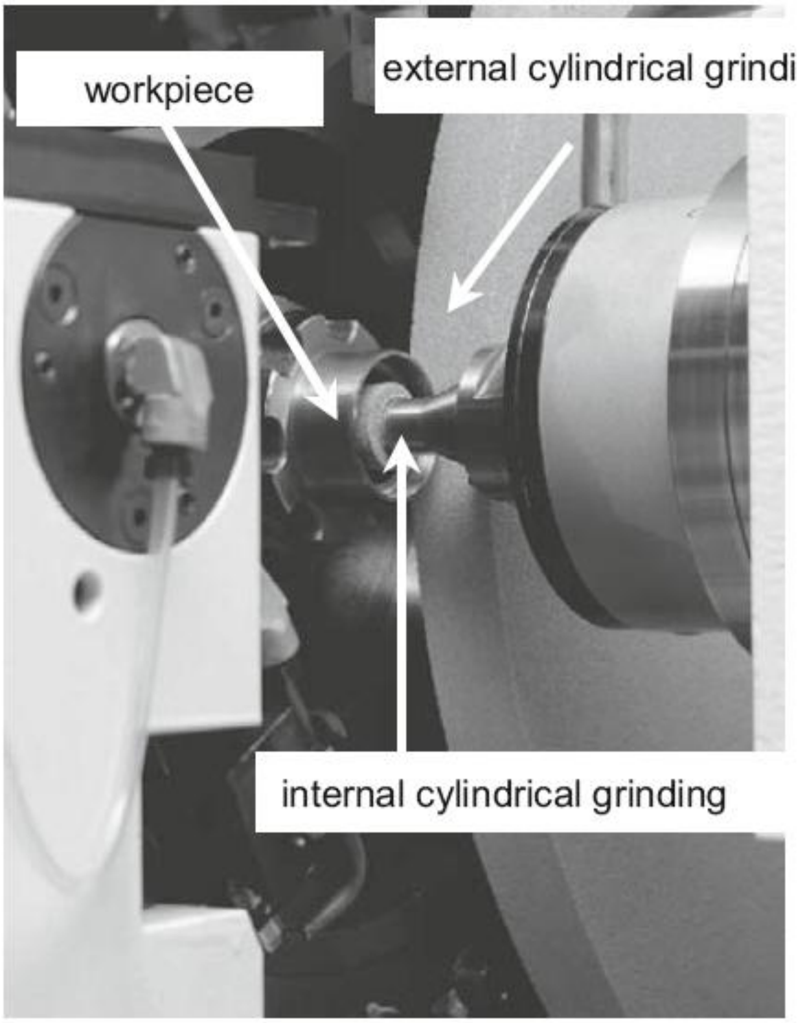


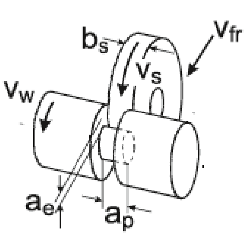
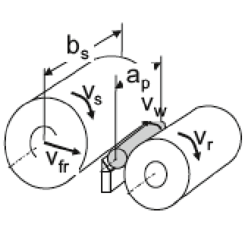
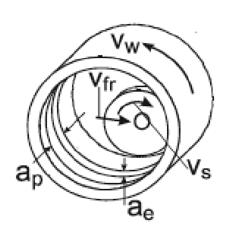
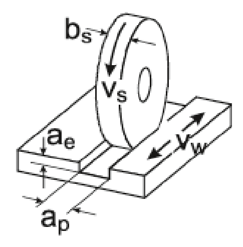
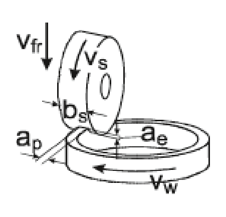
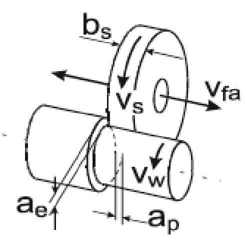
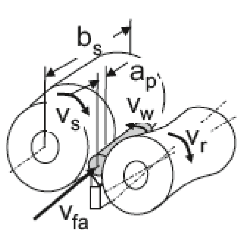
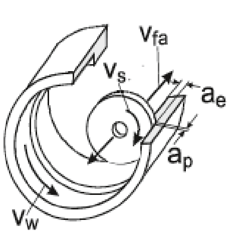
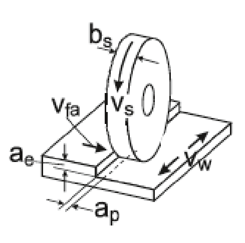
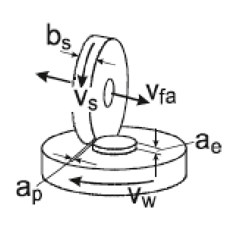
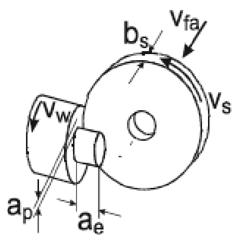
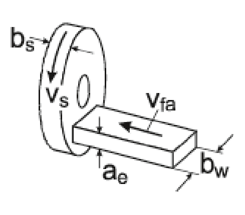
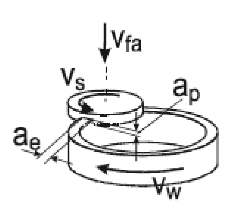
a. grinding of a roll path

b. simultanious grinding of several different bores with a wheel set

c. grinding of a taper bore

In internal cylindrical grinding, the contact arc between the grinding wheel and the workpiece is considerably longer, compared to external grinding operations. In this way, evacuating the chips and maintaining sufficient supply of cooling lubricant at the contact zone is more difficult. For this reason, grinding wheels must be utilised that allow for a so-called free cut at low pressure force and low contact zone temperatures. Such grinding wheels are characterised by a relatively large grit size, low hardness and an open structure. The next figure shows an arrangement for internal and external machining of a liner by grinding. When grinding longer holes with a small diameter, there is a danger that the far-overhanging spindle will be considerably deformed. As a result of such deformations, undesirable deviations in shape and dimension results such asconicity (infeed grinding) and widening of the hole ends (longitudinal grinding).The employable cutting speeds for small tools are often low, since the high spindle speeds necessary cannot be realised or only at considerable cost. The advantages of high cutting speeds (reduction of forces, surface quality improvement, wear reduction) can therefore not be brought into play for the most part. Moreover, the grinding wheels – because of their small dimensions (less grains are engaged more often) and low hardness – are subjected to a high radial wheel wear. For the reasons mentioned, usually only small material removal rates are realizable in internal cylindrical grinding.



	cylindrical			surface	rotation
	external cylindrical		internal		
	between centres	centreless			
peripheral plunge grinding					
peripheral traverse grinding					
side plunge grinding					

Grinding Wheels

A grinding wheel is an expendable wheel that is composed of an abrasive compound used for various grinding (abrasive cutting) and abrasive machining operations. They are used in grinding machines.

The wheels are generally made from a matrix of coarse particles pressed and bonded together to form a solid, circular shape, various profiles and cross sections are available depending on the intended usage for the wheel. They may also be made from a solid steel or aluminum disc with particles bonded to the surface.

The manufacture of these wheels is a precise and tightly controlled process, due not only to the inherent safety risks of a spinning disc, but also the composition and uniformity required to prevent that disc from exploding due to the high stresses produced on rotation.

Properties needed for grinding wheel:

1- A high degree of hardness and toughness in order to facilitate chip formation and to maintain cutting edge sharpness over a longer period.
2- High strength to resist the acting stresses during grinding.
3- High thermal resistance to withstand both the high grinding temperatures.
4- Chemical resistance in order to avoid chemical reactions even at higher pressures and temperatures when interacting with the air, cooling lubricant or workpiece material.
5- High toughness to resist vibrations during grinding.
6- High coefficient of friction to facilitate removal of chip of workpiece.

Wheels abrasive materials:

1. Natural materials:

- They are used for small extensions at which strengths are low except for diamond.

Types of natural materials:

1. **Quartz:**
    - It is composed mainly of silicon oxide (SiO_2) and other impurities as iron oxide (FeO) and titanium dioxide (TiO_2).
    - It is flint or triploid.
    - Hardness reaches 820 HK.
    - It is used in leather and wood manufacturing.
    - Triploid is used in metal-grinding wheels.
2. **Corundum and Emery:**
    - Composed of 80:95% aluminum oxide (Al_2O_3) for corundum and 60% aluminum oxide (Al_2O_3) with iron oxide (Fe_2O_3) for emery.
    - Hardness reaches 2050 HK and toughness is high.
    - Emery is less effective due to low aluminum oxide percentage.
    - They are used in rubber-bonded grinding components, emery paper and unbonded form for polishing optical glasses
3. **Garnet:**
    - Hardness reaches 1360 HK and it has shell-shaped fracture.
    - It is used in abrasive paper for hard and soft wood , as well as in unbonded form in the polishing treatment of optical components.
4. **Natural diamond:**
    - Diamond is chemically pure carbon that crystallizes as a natural product under extreme pressure and heat over a long period of time.
    - Large diamonds of high purity are used in drawing dies, hardness testers, dressing tools and diamond lathes.
    - Other natural diamonds of the purer variety are used in drill bits for the natural gas industry and tunnel-boring machines. Impure, irregular diamonds, so-called “borts”, are used in bonded form for grinding in diverse diamond tools and in loose form for polishing.
    - Natural diamond is primarily used for grinding and slicing glass, ceramic products, and carbides, plastics as well as concrete, and synthetic stones and in stationary and rotating dressing tools.
    - Diamond is not suited for grinding steel for two reasons:

- in grinding, high shear loads arise, as well as high temperatures under low pressures compared with the conditions for the synthesis of diamonds.
- The diffusion of the carbon from the diamond into a material in which carbon is easily dissolved, e.g. steel workpieces. The second mechanism also arises in the grinding conditions described above.

2. Synthetic materials:

- Due to high costs of extraction of natural materials with respect to manufacturing of synthetic ones, low mechanical properties of natural ones and need for purify for some types.
- Corundum and silicon carbide belong to the conventional grinding materials, while CBN and diamond represent the super-abrasive category.

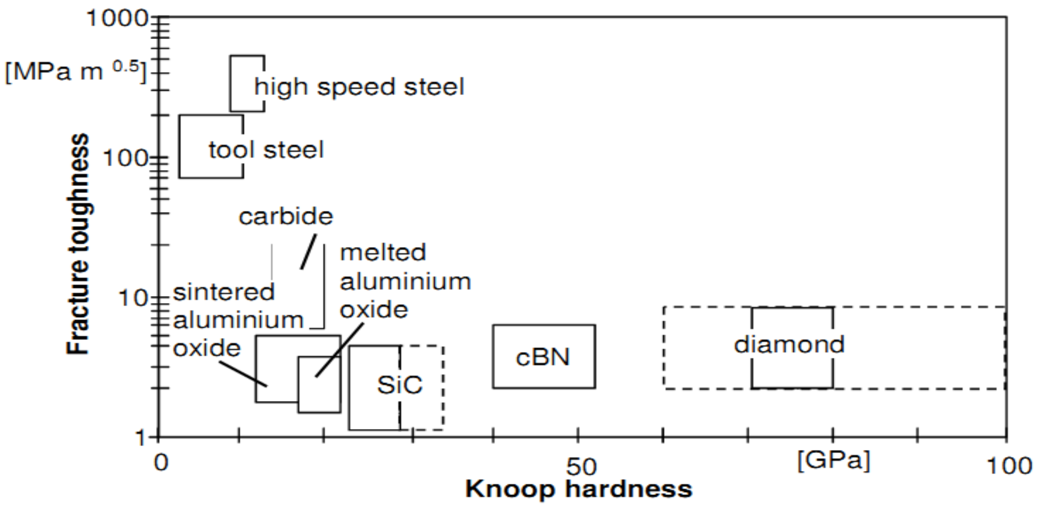


Fig. 3-1. Hardness and fracture toughness of synthetic abrasive grit materials in comparison to a few working materials [HELL93]

- Although the hardness of the grit material is higher than the material to be processed, the toughness of the abrasive is much lower. It is therefore evident that further performance enhancements can be achieved by developing new grit materials with extremely high hardness and sufficient toughness.

Types of synthetic materials and their properties:

	Range of application	Grinding process	Materials
Brown corundum (Bc)	Grinding tools like Wfc, bond: most resin, as well hot-pressed wheels, cut-off wheels	Rough-, cut-off-, off-hand-, (high performance-), belt grinding, cleaning, deburring	Unalloyed, low alloyed steels, cast iron, base metals
Zircon alum. ox.	Wheels, bond: resin, grinding belts, always with NK or SiC	Rough-, high-pressure, (high performance-), belt grinding, cleaning, deburring	Steel casting
Sintered bauxite corundum	Wheels	High-pressure grinding	Austentic steels
Sintered corundum	Wheels, bond:vitrified, pro rata 50 - 90 % EK	Like Wfc and Mcc, (high performance-), belt grinding	Like Wfc and Mcc
Silicon carbide, black	Wheels, cut-off wheels, grinding belts	Rough-, cut-off-, off-hand-, belt grinding	Grey cast iron, aluminum, wood, lacquer
Silicon carbide, green	Wheels, bond: resin	All grinding processes	Grey cast iron, carbide, glass, stone, titanium base alloy, plastics, ceramics
Cubic boron nitride CBN	Wheels, metal (as well galvanic bond), resin bond, vitrified bond, loose abrasive grit	Like Wfc and Mcc	Tempered steels, HSS, low alloyed steels
Diamond	Wheels, metal bond well galvanic), resin bond, loose abrasive grit	Surface-, profile-, cut-off grinding, dressing tools, lapping, polishing	Glass, ceramics, carbide, natural stone, cermets, glass-fibre reinforced plastics, semi-conductor, base metals

Machinability and its effect on grinding:

- Machinability is understood as a property of a material that allows for chip removal under given conditions.
- It thus describes the behavior of a material during chip forming. The machinability of a material must always be considered in conjunction with the machining method, the tool and the machining parameters.

Cooling for grinding:

- The shearing, cutting and rubbing processes involved in grinding generate large heat flow, which can only be removed to a small extent with the chips and thus can lead to considerable thermal stress on the workpiece and the tool, so cooling is very important.
- **Secondary functions of cooling fluids:**
  - Purifying the grinding wheel and the workpiece
  - Chip transport from the machining location
  - Building up corrosion resistance for both the machine and the workpiece material.

Shapes of Grinding wheel:

1. **Straight Grinding wheels:**
   - Straight wheel are the most common mode of wheel that is found on pedestal or bench grinders.
   - This is the one widely used for centreless & cylindrical surface grinding operations.
   - As it is used only on the periphery, it forms a little concave surface on the piece.
   - This is used to gain on several tools like chisels. The size of these wheels differs to a great extent, width & diameter of its face obviously depends on the category of its work, machines grinding power

2. **Cylinder or wheel ring:**
   - A cylinder wheel has no center mounting support but has a long & wide surface.
   - Their width is up to 12" and is used purely in horizontal or vertical spindle grinders.
   - This is used to produce flat surface, here we do grinding with the ending face of the wheel.
3. **Tapered Grinding wheels:**
   - Tapered Grinding wheel is a straight wheel that tapers externally towards the midpoint of the wheel.
   - As this pact is stronger than straight wheels, it accepts advanced lateral loads. Straight wheel with tapered face is chiefly used for gear teeth, grinding thread, etc.

4. **Straight cup:**
   - This Straight cup wheels forms an option for cup wheels in cutter and tool grinders, having an extra radial surface of grinding is favorable.

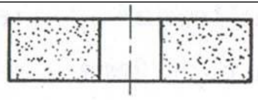
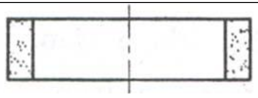
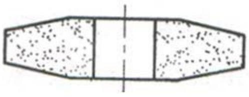
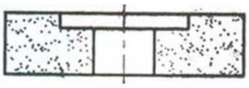
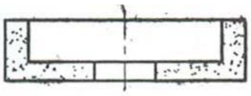
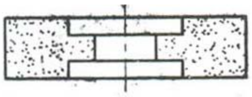
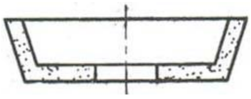
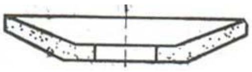
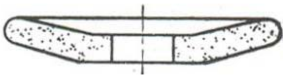
5. **Dish cup:**
   - In fact this is used primarily in jig grinding and cutter grinding. It is a very thin cup-style grinding wheel which permits grinding in crevices and slot.

6. **Saucer grinding Wheels:**
    - Saucer grinding wheel is an exceptional grinding profile used for grinding twist drills and milling cutters. This finds wide usage in non-machining areas, as this saw filers are used by saucer wheels to maintain saw blades.

7. **Diamond wheel:**
    - In diamond wheels industrial diamonds remain bonded to the edge. This is used to grind hard materials like concrete, gemstones & carbide tips. A slitting saw is designed for slicing gemstones like hard materials.

8. **Diamond mandrels:**
    - Diamond mandrels are very similar to their counterpart, a diamond wheel. They are tiny diamond rasps for use in a jig grinder doing profiling work in hard material.

9. **Cut off wheels:**
    - Cut off wheels, also known as parting wheels are self-sharpening wheels that are thin in width and often have radial fibers reinforcing them.
    - They are often used in the construction industry for cutting reinforcement bars (rebar), protruding bolts or anything that needs quick removal or trimming. Most handymen would recognize an angle grinder and the discs they use.

Shape	Name	Applications
	Straight (Type 1)	Cylindrical, centerless, internal, cutter, surface, and offhand grinding operations.
	Cylinder (Type 2)	Surface grinding on horizontal and vertical spindle grinders.
	Tapered (both sides) (Type 4)	Snagging operations; tapered sides lessen the chance of the wheel's breaking.
	Recessed (one side) (Type 5)	Cylindrical, centerless, internal and surface grinders; recess provides clearance for the mounting flange.
	Straight cup (Type 6)	Cutter and tool grinder and surface grinding on vertical and horizontal spindle machines.
	Recessed (both sides) (Type 7)	Cylindrical, centerless and surface grinders; recesses provide clearance for mounting flanges.
	Flaring cup (Type 11)	Cutter and tool grinder; used mainly for sharpening milling cutters and reamers.
	Dish (Type 12)	Cutter and tool grinder; its thin edge permits it to be used in narrow slots.
	Saucer (Type 13)	Saw gumming, gashing milling cutter teeth.

Grinding Wheel Standard Marking System

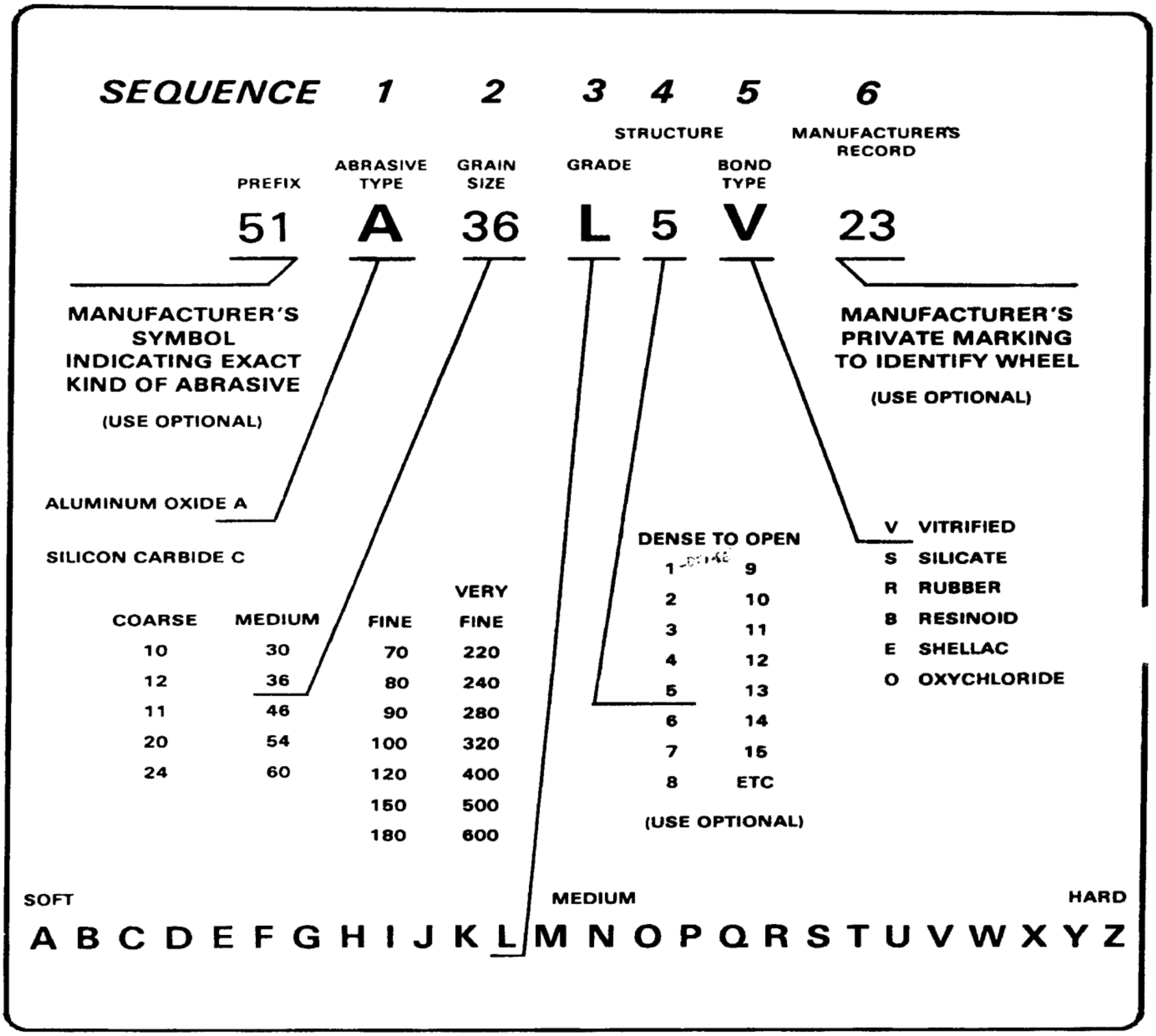


Figure 5-9. Standard system of markings.

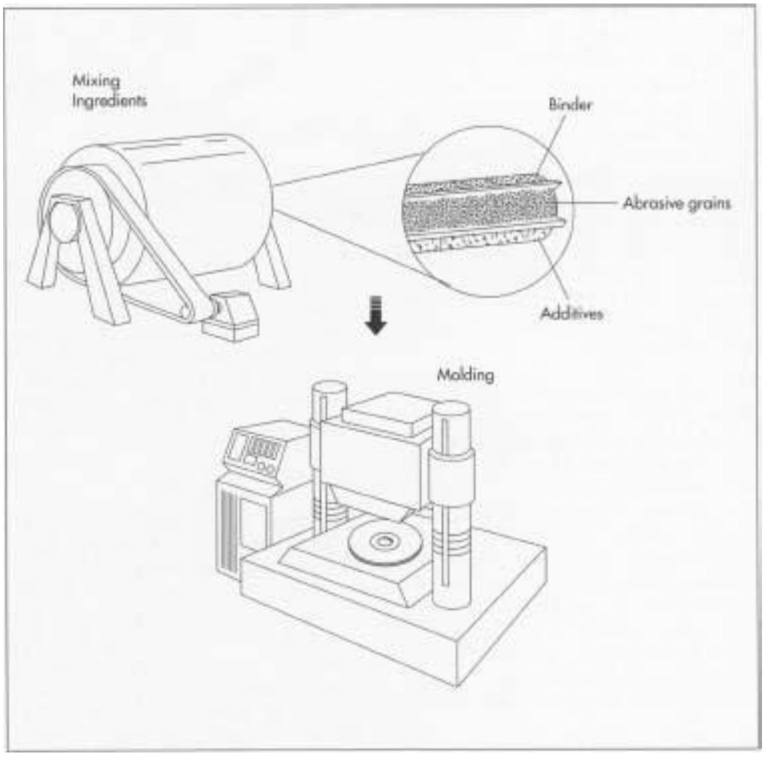
Abrasive Type	**A**60-M5-V
Abrasive size	A**60**-M5-V
Grade/Hardness	A60-**M**5-V
Structure	A60-M**5**-V
Bond	A60-M5-**V**

The ManufacturingProcess

Most grinding wheels are manufactured by the cold-press method, in which a mixture of components is pressed into shape at room temperature. The details of processes vary considerably depending upon the type of wheel and the practices of individual companies. For mass production of small wheels, many portions of the process are automated.

Mixing the ingredients

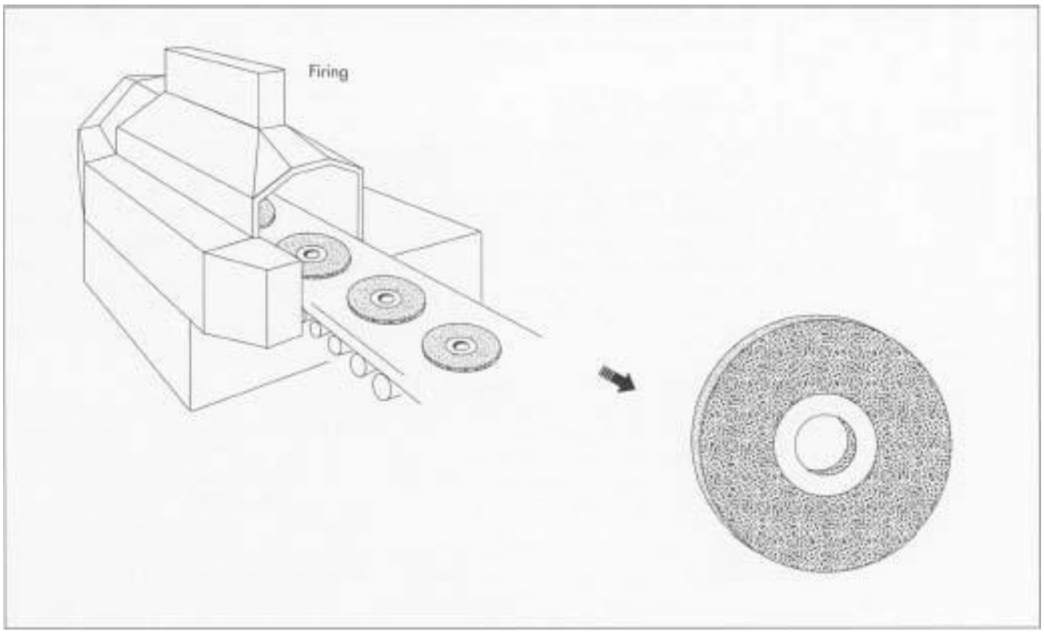
1. Preparing the grinding wheel mixture begins with selecting precise quantities of abrasives, bond materials, and additives according to a specific formula. A binder, typically a water-based wetting agent in the case of vitrified wheels, is added to coat the abrasive grains; this coating improves the grains' adhesion to the binder. The binder also helps the grinding wheel retain its shape until the bond is solidified. Some manufacturers simply mix all materials in a single mixer. Others use separate steps to mix abrasive grains with binder.



Wheel manufacturers often spend considerable effort to develop a satisfactory mixture. The blend must be free-flowing and distribute grain evenly throughout the structure of the grinding wheel to assure uniform cutting action and minimal vibration as the wheel rotates during use. This is particularly important for large wheels, which may be as big as several feet in diameter, or for wheels that have a shape other than the familiar flat disk.

Molding

2. For the most common type of wheel, an annular disc, a predetermined amount of grinding wheel mixture is poured into a mold consisting of four pieces: a circular pin the size of the finished wheel's arbor hole (its center hole); a shell with a 1-inch (2.5-centimeter) wall, about twice as high as the desired grinding wheel is thick; and two flat,



After molding and final shaping, the wheel is fired in an oven or furnace. Firing melts the binder around the abrasives and converts it to a form that will resist the heat and solvents encountered during grinding. Finishing steps that follow firing may include reaming the arbor (center) hole to the proper size, correcting the thickness of the wheel sides, balancing the wheel, and adding labels.

Circular plates with diameter and arbor hole sizes equal to those of the wheel. A variety of methods are used to distribute the mixture evenly. Typically, a straight edge pivots about the center arbor pin to spread the mixture throughout the mold.

3. Using pressures in the range of 100 to 5000 pounds per square inch (psi) for 10 to 30 seconds, a hydraulic press then compacts the mixture into the grinding wheel's final shape. Some manufacturers use gage blocks between the two face plates to limit their movement and establish uniform thickness. Others control wheel thickness by closely monitoring the consistency of the mix and the force of the press.

4. After the mold has been removed from the press and the wheel stripped from the mold, the wheel is placed on a flat, heatproof carrier. Final shaping of the wheel may take place at this time. All work at this stage has to be done very carefully because the wheel is held together by only the temporary binder. Lighter wheels can be lifted by hand at this stage; heavier ones may be lifted with a hoist or carefully slid on a carrier to be transported to the kiln.

Firing

5. Generally, the purposes of the firing are to melt the binder around the abrasives and to convert it to a form that will resist the heat and solvents encountered during grinding. A wide range of furnaces and kilns are used to fire grinding wheels, and the temperatures vary widely depending upon the type of bond. Wheels with a resin bond are typically fired at a temperature of 300 to 400 degrees Fahrenheit (149 to 204 degrees Celsius), and wheels with vitrified bonds are fired to temperatures between 1700 and 2300 degrees Fahrenheit (927 to 1260 degrees Celsius).

Finishing

6. After firing, wheels are moved to a finishing area, where arbor holes are reamed or cast to the specified size and the wheel circumference is made concentric with the center. Steps may be necessary to correct thickness or parallelism of wheel sides, or to create special contours on the side or circumference of the wheel. Manufacturers also balance large wheels to reduce the vibration that will be generated when the wheel is spun on a grinding machine. Once wheels have received labels and other markings, they are ready for shipment to the consumer.

Grinding Wheel Wear

As a result of process forces during grinding, a grinding wheel is subject to modification by aprocess of wheel wear. Wear leads to changed process conditions and quality deviations in thecomponent.

In plunge grinding, where the wheel profile is reproduced in the ground component, profiledeviations lead to workpiece shape defects. In the case of longitudinal grinding, profile deviationslead to screw thread undercuts. Roundness deviations make the machine system vibrate by dynamicalternating forces, which cause chatter marks to be machined on the component.

Loss of grinding wheel sharpness leads to higher grinding forces, which may entail dynamicand thermal deflections between the grinding wheel and workpiece, as well as uncontrolled grindingprocesses leading to chatter marks on the component. Finally, there will be shape and positionerrors, as well as dimensional deviations on the component. These modifications of the grindingwheel in the course of the grinding process are due to wear and result from microscopic changesin the abrasive grains and alterations in the chip space.

Wheel Wear Mechanisms

Wheel wear results from material loss at the wheel surface, which can be traced back to mechanicalcontact between the wheel moving relative to the workpiece or any other body such as the dressingtool. Wear effects can be ascribed to the following main mechanisms: abrasion, adhesion, tribochemicalreactions, surface disruption, and diffusion.

1. Abrasive Wheel Wear

As a prerequisite of abrasive wear, the surface of one of the two interacting partners of the abrasiveprocess must be penetrated and a tangential movement must take place between them. The resultis plastic and elastic deformations with groove and chip formation in the microrange. Groovingwear dominates, when hard workpiece material particles or loose particles of grain in the contactzone lead to surface changes in the wheel.

2. **Adhesive Wheel Wear**

Adhesion wear is based on an atomic bond at a microcontact surface between the active partnersof the wear process through microwelding. This bond is very strong, which means that shearingthrough the relative movement of the active parts takes place at a different place than that of theoriginal microcontact surface. Chemical adhesion is based on atomic interaction through thermallyinduced diffusion processes. In contrast, in mechanical adhesion, the surfaces of the active partsare engaged in the microrange, while high temperatures lead to surface deformation.

3. **Tribochemical Wheel Wear**

In the case of tribochemical wear, chemical reactions take place either between the active partnersof the wear process or with the surrounding environmental medium. These chemical reactions causechanges in the boundary layer properties, which lead to adhesion of reaction products on the abrasivegrain and to grain damage. Factors of a tribochemical reaction are chemical affinity between theactive partners and ambient conditions such as temperature, pressure, and concentration.

4. **Surface Disruptions**

Surface disruptions can be traced back to mechanical thermal alternating pressures opening upgrain boundaries and cleavage planes. This leads to structure changes, fatigue, cracks, and separationof single particles causing breakage and cutting material failure.

5. **Diffusion**

Prerequisites of diffusion processes in the working zone are the adequate activation energy and asufficient chemical potential of the active partners. The diffusion accounts for a thermal activationof single atoms, which, as a result, change places. This causes material loss, and impurity atomsare inserted into the grain surface, which might lead to a loss of hardness. Surface diffusionprocesses can be divided into intercrystalline diffusion along the grain boundaries and transcrystallinediffusion into the grain volume.